

History of aerospace in Huntsville  
saturn history  
8/1/66

X.9.

X 9

**GEORGE C. MARSHALL SPACE FLIGHT CENTER**

**HUNTSVILLE, ALABAMA**

SATURN HISTORY DOCUMENT  
University of Alabama Research Institute  
History of Science & Technology Group

Date ----- Doc. No. -----

**DIGEST OF  
FY-64 FUNDED ADVANCED STUDIES  
AUGUST 1966**

National Aeronautics and Space Administration



GEORGE C. MARSHALL SPACE FLIGHT CENTER

DIGEST OF  
FY-64 FUNDED ADVANCED STUDIES

AUGUST 1966

PREPARED BY:  
WILLIAM R. PAYNE  
RESOURCES MANAGEMENT OFFICE  
ADVANCED SYSTEMS OFFICE

## TABLE OF CONTENTS

	PAGE
INTRODUCTION.....	1
SECTION I. LAUNCH VEHICLE AND SUPPORTING STUDIES.....	2
A. Launch Vehicle Component Cost.....	2
B. Launch Vehicle Cost Parameters.....	2
C. Human Engineering Data And Concepts for Handling Advanced Nuclear Systems in Space...	3
D. Operational Safety Analysis: Advanced Nuclear Mission.....	4
E. Human Engineering Requirements: Ground Support of Nuclear Systems.....	4
F. Launch Vehicle Cost Model.....	5
G. Reusable Orbital Transport (First Stage).....	6
H. Reusable Orbital Transport (Second Stage).....	6
I. Recovery and Reusability: S-IC Stage.....	7
J. Post-Saturn Launch Vehicles.....	7
K. Advanced Nuclear System Parameters.....	8
L. Saturn IB Improvements.....	9
M. Saturn V Improvements.....	10
N. Launch Vehicle System Criteria.....	11
SECTION II. EARTH ORBITAL STUDIES.....	13
A. Advanced Orbital Launch Operations.....	13
B. Orbital Tanker Design.....	13
C. Orbital Launch Facility.....	14
D. Utilization of Spent Stages.....	14
E. Orbital and Lunar Flight Handbook.....	15
SECTION III. LUNAR STUDIES.....	16
A. Apollo Logistics Support Systems (ALSS).....	16
B. Lunar Flying Vehicle.....	17
C. Operations and Logistics (LESA).....	17
D. Communications and Control (LESA).....	18
E. Human Factors and Environmental Control (LESA).....	19
SECTION IV. PLANETARY STUDIES.....	20
A. Planetary Transportation Systems Model.....	20
B. Manned Mars and Venus Exploration.....	21
C. Low Acceleration Space Transportation Systems..	21
D. Manned Mars Surface Operations.....	22
E. Mission Requirements: Manned Mars and Venus Exploration.....	23

## INTRODUCTION

This publication is one of a series to summarize the advanced study program for each fiscal year beginning with FY-61. A separate report covers the study program for each fiscal year. The purpose of these documents is to provide historical reference information which should be helpful in planning future study programs.

The FY-64 funded studies are covered in this document. These investigations are covered under four categories: Launch Vehicle and Supporting Studies; Earth Orbital Studies; Lunar Studies; and Planetary Studies. The information presented on each study includes a brief description of the objectives and results and pertinent contract data.

In order to keep this report small and easy to use, no attempt was made to include conclusions based on the study results; however, the final reports documenting the investigations are referenced. If these reports are needed for permanent retention and are not available from the Technical Supervisor or the MSFC Library (MS-IPL), submit requests for the documents to the Scientific and Technical Information Facility, Attention: NASA Representative, P.O. Box 33, College Park, Maryland 20740.

## SECTION I. LAUNCH VEHICLE AND SUPPORTING STUDIES

### A. LAUNCH VEHICLE COMPONENT COST

#### Objectives and Results

The objectives of this effort were to develop a valid and consistent cost estimating and evaluation model to provide the necessary relative and reliable cost effectiveness answer which planners can employ as guidelines for the economic evaluation of future vehicle concepts in comparison with existing systems. Cost estimating relationships as a function of cost-indicative design parameters for Saturn V and beyond were developed. These relationships were derived at the component or subsystem level. The resulting model provides the capability of estimating costs for production, development and facilities, and refurbishment of recoverable vehicles.

The results of the study are contained in the following final report:

"Launch Vehicle Component Costs Study," Contract No. NAS8-11368, Report No. LMSC-895429, Lockheed Missiles and Space Company, April 28, 1965, UNCLASSIFIED.

#### Contract Data

1. Contractor: Lockheed Missiles and Space Company
2. Contract No.: NAS8-11368
3. Period of Performance: June 64 - June 65
4. Contract Amount: \$139,000
5. Technical Supervisor: C. Rutland

### B. LAUNCH VEHICLE COST PARAMETERS

#### Objectives and Results

In general, the objectives of this study were to provide a general methodology for the routine consideration of cost dynamics and cost implications involved in satisfying the requirements of a selected group of general contingencies. Typical contingencies considered were acceleration, cancellation, stretchout, and similar cost related activities. The study was to obtain a better understanding of those factors which influence the complete launch vehicle program cost by determining the extent and manner of influence of cost parameters.

The results of the study are documented in the following final reports:

1. "Launch Vehicle Cost Parameters Study," Contract No. NAS8-11329, Report No. FZM-4247, General Dynamics/Ft. Worth, May 27, 1965, UNCLASSIFIED.
2. "Launch Vehicle Cost Parameters," Contract No. NAS8-11464, Report No. CR-65-30, Martin/Denver, May 1965, UNCLASSIFIED.

Contract Data

1. Contractor: General Dynamics/Ft. Worth
  - a. Contract No.: NAS8-11329
  - b. Period of Performance: June 64 - May 65
  - c. Contract Amount: \$97,000
  - d. Technical Supervisor: R. Voss
2. Contractor: Martin/Denver
  - a. Contract No.: NAS8-11464
  - b. Period of Performance: June 64 - May 65
  - c. Contract Amount: \$98,000
  - d. Technical Supervisor: R. Voss

C. HUMAN ENGINEERING DATA AND CONCEPTS FOR HANDLING ADVANCED NUCLEAR SYSTEMS IN SPACE

Objectives and Results

This study was initiated as a corollary to the AOLO studies performed in CY-64. The investigation was performed to provide information needed concerning man's contribution to orbital launch operations of nuclear systems and to define experiment and engineering tests that must be performed early in orbital research laboratories. The study was to determine what man can do in handling and operating nuclear systems in space, when the job should be performed, where it should be done, and what are the alternative methods of performing the jobs.

Details of the study are contained in the following final report:

"Human Engineering Data and Concepts for Handling Advanced Nuclear Systems in Space," Contract No. NAS8-11425, Report No. CR-65-88, Martin/Denver, July 1965, UNCLASSIFIED.

Contract Data

1. Contractor: Martin/Denver
2. Contract No.,: NAS8-11425
3. Period of Performance: June 64 - June 65
4. Contract Amount: \$98,000
5. Technical Supervisor: J. Hilchey

D. OPERATIONAL SAFETY ANALYSIS: ADVANCED NUCLEAR MISSIONS

Objectives and Results

The purpose of this study was to investigate and assess the nature and magnitude of nuclear-safety problems involved in the operational use of advanced nuclear space vehicles. The study was to define, in general terms, the safety criteria, safety systems, and operating techniques necessary to maintain nuclear safety at an acceptable level for those situations within environments beyond the Earth's atmosphere.

The results of the study are documented in the following final report:

"Operational Safety Analysis for Advanced Nuclear Missions,"  
Contract No. NAS8-11131, Report No. FZK-221, General  
Dynamics/Ft. Worth, December 31, 1964, UNCLASSIFIED.

Contract Data

1. Contractor: General Dynamics/Ft. Worth
2. Contract No.: NAS8-11131
3. Period of Performance: November 63 - December 64
4. Contract Amount: \$97,000
5. Technical Supervisor: H. Manning

E. HUMAN ENGINEERING REQUIREMENTS: GROUND SUPPORT OF NUCLEAR SYSTEMS

Objectives and Results

The objectives of this effort were to develop human engineering criteria useful to the system engineer in the design of advanced reusable nuclear space systems and associated ground facilities and ground support equipment. These criteria were to include time, doctrine, operational concepts, software and hardware design features.

The details of the study results are documented in the following final report:

"Human Engineering Data for Advanced Ground Support Operations with Nuclear Space Systems," Contract No. NAS8-11188, Report No. SM-48721, Douglas Aircraft Company, June 1965, UNCLASSIFIED.

Contract Data

1. Contractor: Douglas Aircraft Company
2. Contract No. NAS8-11188
3. Period of Performance: June 64 - May 65
4. Contract Amount: \$74,000
5. Technical Supervisor: H. Manning

F. LAUNCH VEHICLE COST MODEL

Objectives and Results

This was a continuation of work performed with FY-63 funds. The purpose of this effort was to develop a cost methodology directed toward the evolution of a conceptual framework which could be applied to different technologies and mission concepts. These studies resulted in the formulation of a technique which can be used to define the complete developmental and operational cost of a wide range of launch vehicles encompassing all technologies and representing both current and proposed vehicle concepts.

The details of the study are documented in the following final report:

"Launch Vehicle Systems Cost Model," Contract No. NAS8-11283, Report No. FZM-4404, General Dynamics/Ft. Worth, May 27, 1965, UNCLASSIFIED.

Contract Data

1. Contractor: General Dynamics/Ft. Worth
2. Contract No.: NAS8-11283
3. Period of Performance: June 64 - June 65
4. Contract Amount: \$138,000
5. Technical Supervisor: T. Sharpe



G. REUSABLE ORBITAL TRANSPORT (FIRST STAGE)

Objectives and Results

This study was performed to provide planning data to be used as a base for definition of additional studies eventually leading to program definition for the reusable orbital transport. Previous studies led to a 2-stage all-rocket system with cargo and passenger compartments integrated into the second stage. From this baseline system, this effort resulted in tradeoffs which were used to comparatively evaluate the system. This effort considered the first stage, the ground complex, and overall system integration. A concurrent study considered the second stage of the system.

The results of the first stage investigation are contained in the following final report:

"Design Studies of a Reusable Orbital Transport, First Stage," Contract No. NAS8-11319, Report No. LR-18790, Lockheed California Company, May 21, 1965, UNCLASSIFIED.

Contract Data

1. Contractor: Lockheed California Company
2. Contract No.: NAS8-11319
3. Period of Performance: June 64 - August 65
4. Contract Amount: \$776,000
5. Technical Supervisor: L. Spears

H. REUSABLE ORBITAL TRANSPORT (SECOND STAGE)

Objectives and Results

This study was performed concurrently with one investigating the first stage of a reusable orbital transport which evolved from previous studies. The purpose of the effort was to provide planning data to be used as a base for definition of additional studies eventually leading to program definition of the system. This study resulted in definition of an attractive second stage vehicle for the reusable orbital transport system. It provides acceptable performance within the constraints of mission requirements, passenger comfort and safety, and ease of development.

The details of the effort are contained in the following final report:

"Reusable Orbital Transport, Second Stage," Contract No. NAS8-11463, Report No. GD/C-DCB-65-018, General Dynamics, April 1965, UNCLASSIFIED.

Contract Data

1. Contractor: General Dynamics
2. Contract No.: NAS8-11463
3. Period of Performance: June 64 - June 65
4. Contract Amount: \$492,000
5. Technical Supervisor: D. Fellenz

I. RECOVERY AND REUSABILITY: S-IC STAGE

Objectives and Results

The objective of this study was to investigate nonwinged methods of S-IC recovery for refurbishment and reuse, and to compare the effectiveness of the selected method or methods with the fixed-wing recovery system previously studied. The purpose of such a recovery system is to reduce the effective costs of launching payloads. Several candidate systems were investigated and the selected candidate investigated in greater depth in the areas of design, performance, operational methods, and costs. The study also updated the fixed-wing design from latest wind tunnel test results. Quantitative and subjective comparisons were also made of the selected systems and the fixed-wing version for launch rates of 60 to 120 per 10-year period.

The results of the study are documented in the final report listed below:

"Study of Saturn S-IC Recovery and Reusability," Contract No. NAS8-11280, Report No. D2-23722, Boeing Company, December 1964, UNCLASSIFIED.

Contract Data

1. Contractor: Boeing Company
2. Contract No.: NAS8-11280
3. Period of Performance: June 64 - January 65
4. Contract Amount: \$196,000
5. Technical Supervisor: G. Detko

J. POST-SATURN LAUNCH VEHICLES

Objectives and Results

This effort was a continuation of previous studies to define the next large launch vehicle after Saturn V. This study considered

three major areas: design analysis, mission analysis, and technology. Detailed design studies were conducted of the most promising concepts, particularly in areas that have the greatest effect on the overall vehicle system. The desirability and optimum timing of the anticipated Post-Saturn development program was determined by comparing it with potential mission requirements and existing launch vehicle capabilities. This was done to better establish what size space program or missions could economically justify the development of a larger vehicle, what payload capability it should have, and when the larger vehicle should be available. The study also continued the effort to identify problem areas requiring supporting research and technology activity.

The results of this study are contained in the final report listed below:

"Post-Saturn Launch Vehicle Study - Part III, Final Report,"  
Contract No. NAS8-11123, Report No. ER-12603, Martin/Baltimore,  
November 1964, CONFIDENTIAL.

#### Contract Data

1. Contractor: Martin/Baltimore
2. Contract No.: NAS8-11123
3. Period of Performance: October 63 - November 64
4. Contract Amount: \$1,499,000
5. Technical Supervisor: W. Huber

#### K. ADVANCED NUCLEAR SYSTEM PARAMETERS

##### Objectives and Results

This was a continuation of a previous study effort. The objective was to obtain data to permit identification and definition of essential design requirements for an operational nuclear space propulsion system with 1970-1980 availability. The study was to define engine configurations and system parameters required for: (1) Delivery of passengers and/or cargo into lunar orbit; (2) representative unmanned planetary and solar probes; and (3) stages for interplanetary vehicles. Engine requirements for representative manned planetary missions were also to be investigated.

The results of this effort along with the FY-63 funded effort are documented in the following final report:

"Mission Oriented Advanced Nuclear System Parameters Study,"  
Contract No. NAS8-5371, Report No. 8423-6007-RU000, TRW Space  
Technology Laboratories, March 1965.

### Contract Data

1. Contractor: TRW Space Technology Laboratories
2. Contract No.: NAS8-5371
3. Period of Performance: May 64 - May 65 (Follow-on)
4. Contract Amount: \$250,000 (Follow-on); Total \$400,000
5. Technical Supervisor: W. Jordan

## L. SATURN IB IMPROVEMENTS

### Objectives and Results

Two studies were performed concurrently to investigate modifications to the Saturn IB launch vehicle that would provide increased payload capability for post-Apollo missions. The modifications include: Up-rated liquid rocket engines, increased propellant capacity, and/or substitute propellants in the S-IB stage; solid rocket boost assist for the S-IB stage; application of an S-IVB stage with advanced propulsion in combination with the basic or up-rated S-IB stage; and the application of a cryogenic third stage to the basic and up-rated Saturn IB vehicles.

The results of the studies are contained in the following final reports:

1. "Saturn IB Improvement Study, Solid First Stage," Contract No. NAS8-11370, Report No. SM-47043, Douglas Aircraft Company, February 25, 1965, UNCLASSIFIED.
2. "Saturn IB Improvement Study, Liquid First Stage and Boost Assist," Contract No. NAS8-11369, Report No. AE-PB-654, Chrysler Corporation, May 1965, UNCLASSIFIED.

### Contract Data

1. Contractor: Douglas Aircraft Company
  - a. Contract No.: NAS8-11370
  - b. Period of Performance: June 64 - May 65
  - c. Contract Amount: \$99,000
  - d. Technical Supervisor: C. Zimmerman/M. Page
2. Contractor: Chrysler Corporation
  - a. Contract No.: NAS8-11369
  - b. Period of Performance: July 64 - April 65
  - c. Contract Amount: \$170,000
  - d. Technical Supervisor: C. Zimmerman/M. Page

## M. SATURN V IMPROVEMENTS

### Objectives and Results

This effort consisted of a series of six studies by Saturn stage contractors to determine growth potential of the Saturn V vehicles for potential future missions, and to obtain comparisons of alternative uprating methods in terms of payload gains achievable, costs, lead times, impact on facilities, etc. Methods of uprating considered were: Thrust uprating of F-1 engines and increased propellant capacities; addition of a sixth F-1 in the S-IC stage plus increased propellant capacities; use of large solid motor boost assist; addition of J-2 engines in the S-II stage plus increased upper stage propellant capacities; and improved or advanced upper stage engines plus increased propellant capacities.

The studies are documented in the reports listed below:

1. "Modified Launch Vehicle (MLV) Saturn V Improvement Study Composite Summary Report," NASA Technical Memorandum TMX-53252, MSFC, July 2, 1965.
2. "Design Study of the MS-IC Stage for the Modified Launch Vehicle (MLV) Saturn V," Contract No. NAS8-11339, Report No. D5-11420, Boeing Company, April 15, 1965.
3. "Design Study of the MS-II Stage for the Modified Launch Vehicle (MLV) Saturn V," Contract NAS8-11352, Report No. SID 65-244, North American Aviation, April 29, 1965.
4. "Saturn V Improvement Study, MS-IVB-1 and MS-IVB-2," Contract No. NAS8-11359, Report No. SM-47090, Douglas Aircraft Company, April 15, 1965.
5. "Saturn V Improvement Study, Fluid and Flight Mechanics," Contract NAS8-11428, Report No. D5-13109, Boeing Company, April 30, 1965.
6. "Saturn V Improvement Study, Liquid-Solid System Integration," Contract No. NAS8-11443, Report No. D5-13087, Boeing Company, April 30, 1965.
7. "Study of Resources Required for MLV-Saturn V-4(S) and MLV-Saturn V-4(S)A, Liquid-Solid System Integration," Contract No. NAS8-11478, Report No. D5-13118, Boeing Company, undated.

Contract Data

1. Contractor: Boeing Company
  - a. Contract No.: NAS8-11339
  - b. Period of Performance: June 64 - April 65
  - c. Contract Amount: \$215,000
  - d. Technical Supervisor: W. Corcoran
2. Contractor: North American Aviation
  - a. Contract No.: NAS8-11352
  - b. Period of Performance: June 64 - May 65
  - c. Contract Amount: \$217,000
  - d. Technical Supervisor: W. Corcoran
3. Contractor: Douglas Aircraft Company
  - a. Contract No.: NAS8-11359
  - b. Period of Performance: June 64 - May 65
  - c. Contract Amount: \$209,000
  - d. Technical Supervisor: W. Corcoran
4. Contractor: Boeing Company
  - a. Contract No.: NAS8-11428
  - b. Period of Performance: June 64 - April 65
  - c. Contract Amount: \$246,000
  - d. Technical Supervisor: H. Thomae
5. Contractor: Boeing Company
  - a. Contract No.: NAS8-11443
  - b. Period of Performance: June 64 - April 65
  - c. Contract Amount: \$227,000
  - d. Technical Supervisor: A. Boyanton
6. Contractor: Boeing Company
  - a. Contract No.: NAS8-11478
  - b. Period of Performance: October 64 - May 65
  - c. Contract Amount: \$80,000
  - d. Technical Supervisor: A. Boyanton

N. LAUNCH VEHICLE SYSTEM CRITERIA

Objectives and Results

The object of this effort was to develop basic evaluation criteria, desirable key design features, and promising advanced concepts for future launch vehicle systems. Two approaches were taken: The first was a study of historical trends extrapolated to the near future; the second study investigated future launch needs by looking backward in time, i.e., from the time of a possible global rocket transport back

to the present. The studies included a review of past systems and a mission survey from which criteria and design features were chosen. The criteria and design features were related to derive promising concepts. The derived concepts were evaluated to substantiate the validity of the evaluation criteria and to identify key design features.

The results of this effort are documented in the final reports listed below:

1. "System Criteria for Launch Vehicle Systems," Contract No. NAS8-11429, Report No. D2-90640, Boeing Company, May 1965, UNCLASSIFIED.
2. "Study to Develop System Criteria for Reusable Launch Vehicle Concepts," Contract No. NAS8-11386, Report No. SID 65-848, North American Aviation, June 30, 1965, UNCLASSIFIED.

#### Contract Data

1. Contractor: Boeing Company
  - a. Contract No.: NAS8-11429
  - b. Period of Performance: June 64 - May 65
  - c. Contract Amount: \$247,000
  - d. Technical Supervisor: H. Koelle/L. Spears
2. Contractor: North American Aviation
  - a. Contract No.: NAS8-11386
  - b. Period of Performance: June 64 - May 65
  - c. Contract Amount: \$300,000
  - d. Technical Supervisor: L. Spears/H. Koelle

## SECTION II. EARTH ORBITAL STUDIES

### A. ADVANCED ORBITAL LAUNCH OPERATIONS

#### Objectives and Results

This was a follow-on effort evolving from several previous studies. This effort (Phase B) continued the study of orbital launch operations in support of manned planetary and lunar missions with some change in emphasis from Phase A. In general, the Phase B effort objectives were to develop an operational concept for orbital launch operations (OLO) and develop a feasible evolution for OLO.

The results of the study are contained in the final report listed below:

"Final Report, Advanced Orbital Launch Operations, Phase B,"  
Contract No. NAS8-5344, Report No. 00.676, Ling-Temco-  
Vought, November 1, 1965, UNCLASSIFIED.

#### Contract Data

1. Contractor: Ling-Temco-Vought
2. Contract No.: NAS8-5344
3. Period of Performance: May 64 - October 65 (Phase B)
4. Contract Amount: \$228,000 Phase B; Total \$578,000
5. Technical Supervisor: L. Ball/J. Carter

### B. ORBITAL TANKER DESIGN

#### Objectives and Results

The objectives of this effort were to develop firm conceptual designs of the orbital tanker, evaluate performance and flight dynamics, derive parametric data, determine reliability, define systems checkout, determine costs and cost effectiveness, and prepare a research, development, testing, and evaluation plan.

The results of the effort are contained in the following final report:

"Orbital Tanker Design Data Study," Contract No. NAS8-11326,  
Report No. LMSC-A748410, Lockheed Missiles and Space  
Company, May 30, 1965, UNCLASSIFIED.



### Contract Data

1. Contractor: Lockheed Missiles and Space Company
2. Contract No.: NAS8-11326
3. Period of Performance: June 64 - April 65
4. Contract Amount: \$221,000
5. Technical Supervisor: J. Schwartz

## C. ORBITAL LAUNCH FACILITY

### Objectives and Results

This study was a part of the overall orbital launch operations investigation. The purpose of the OLF study was to provide reasonable estimates of the design, development, testing, and operating requirements for an orbiting facility which would provide needed support in the orbital launch of a manned interplanetary vehicle. The study was to: Conceptually design an initial OLF; determine the operational activities that dictate gravitational design criteria; identify supporting research and technology problems; develop a design evolution plan; establish ORL experiments necessary in the development of the OLF; and determine feasibility and design effects of conducting scientific experiments aboard the OLF.

The results of the study are contained in the following final report:

"Orbital Launch Facility Study," Contract No. NAS8-11355,  
Report No. D2-82559, Boeing Company, October 1965,  
UNCLASSIFIED.

### Contract Data

1. Contractor: Boeing Company
2. Contract No.: NAS8-11355
3. Period of Performance: June 64 - September 65
4. Contract Amount: \$150,000
5. Technical Supervisor: T. Carey

## D. UTILIZATION OF SPENT STAGES

### Objectives and Results

This study relates to investigations of the practicality and desirability of utilizing spent launch vehicle stages and modules to support Earth orbital operations and functions after successfully

completing the principal mission. Emphasis was placed primarily on determining those uses that afford the greatest utility with minimum degradation to the original mission. Criteria and a methodology for evaluation of each concept was established. Cost estimates associated with the design and implementation of the various concepts were prepared and can be used to indicate resource requirements. Research requirements directly applicable to the candidate concepts were identified.

The results of the study are documented in the following final report:

"Utilization of Spent Launch Vehicle Stages in Support of Earth Orbital Missions," Contract No. NAS8-11379, Report No. SID 65-468, North American Aviation, May 31, 1965  
UNCLASSIFIED.

#### Contract Data

1. Contractor: North American Aviation
2. Contract No.: NAS8-11379
3. Period of Performance: September 64 - May 65
4. Contract Amount: \$100,000
5. Technical Supervisor: W. Perry

#### E. ORBITAL AND LUNAR FLIGHT HANDBOOK

##### Objectives and Results

This was a continuation of previous effort which resulted in two handbooks (Earth-orbital and lunar) needed by preliminary design engineers and mission planners in the area of flight mechanics and systems performance. FY-63 funded efforts updated the documents and added some new data. The purpose of this extension of the effort was to strengthen and update the Lunar Flight Handbook through the study of four relevant topics and preparation of an addendum to the handbook. The topics studied were: Moon-to-Earth orbital departure windows; lunar orbit estimation; lunar orbiter theory; and stability and mission potential of the libration points in Earth-Moon system.

The results of this extension are documented in the following document:

"Extension of Effort for Lunar Flight Handbook," Contract NAS8-5031, Report No. ER-13550, Martin Company, December 1964, UNCLASSIFIED.

Contract Data

1. Contractor: Martin Company
2. Contract No.: NAS8-5031
3. Period of Performance: January 64 - December 64 (Phase III)
4. Contract Amount: \$49,800 (Phase III); Total \$251,000
5. Technical Supervisor: C. Swanson

### SECTION III. LUNAR STUDIES

#### A. APOLLO LOGISTICS SUPPORT SYSTEMS (ALSS)

##### Objectives and Results

This effort was to prepare a preliminary design and specification for a Mobile Lunar Laboratory (MOLAB). The MOLAB is a lunar surface vehicle concept capable of supporting a two-man, 14-day scientific mission on the lunar surface and operating within a circular area of at least 80 km radius of the landing point. A resource analysis was to be prepared which identifies the manpower, dollars, time, and facilities necessary for the design, development, fabrication, testing, and delivery of five operational vehicles and supporting equipment. Existing and planned Apollo hardware was to be used where possible. A new conceptual design was to be prepared of an Apollo Extension System (AES) payload for lunar surface exploration. This payload, which would be delivered to the lunar surface by an unmanned modified LEM, consists of a LEM-Shelter, scientific equipment, and mobility aids. The Mobility Test Article, which is a test bed for surface mobility concepts, definition and design was to be initiated.

The results of this effort are documented in the following final reports:

1. "Apollo Logistics Support System (ALSS) Payloads," Contract No. NAS8-11411, Report No. D2-83001, Boeing Company, June 1965, UNCLASSIFIED.
2. "Apollo Logistics Support Systems Payloads Preliminary Design Study," Contract NAS8-11287, Report No. ALSS-TR-013, Bendix Corporation, June 1965, UNCLASSIFIED.

##### Contract Data

1. Contractor: Bendix Corporation
  - a. Contract No.: NAS8-11287
  - b. Period of Performance: June 64 - June 65
  - c. Contract Amount: \$800,000
  - d. Technical Supervisor: H. Schaefer
2. Contractor: Boeing Company
  - a. Contract No.: NAS8-11411
  - b. Period of Performance: June 64 - June 65
  - c. Contract Amount: \$800,000
  - d. Technical Supervisor: H. Schaefer

## B. LUNAR FLYING VEHICLES

### Objectives and Results

This study was to establish conceptual designs and preliminary estimates of development schedules and costs for rocket powered lunar flying vehicles to be used in early lunar surface exploration missions. The primary purpose of these vehicles is to transport astronauts back to the LEM from a disabled surface roving vehicle (MOLAB). A secondary mission is to supplement the surface vehicle by permitting flight to areas which are inaccessible to surface vehicles. The recommended concept is an open cockpit vehicle which can carry two pressure-suited astronauts up to 50 miles. The vehicle has a dry weight of 403 Earth pounds, and a wet weight of 979 pounds. It uses five 100-pound thrust rockets for support with six 10-pound thrust rockets for altitude control.

The details of the study are documented in the final report listed below:

"A Study of Lunar Flying Vehicles," Contract NAS8-11387; Report No. 7217-902002, 7217-920001, 7217-948001, 7217-928001, 7217-950001; Bell Aerosystems Company, June 1965, UNCLASSIFIED.

### Contract Data

1. Contractor: Bell Aerosystems Company
2. Contract No.: NAS8-11387
3. Period of Performance: June 64 - June 65
4. Contract Amount: \$199,000
5. Technical Supervisor: L. Bradford

## C. OPERATIONS AND LOGISTICS (LESA)

### Objectives and Results

The objective of this effort was to define the operational and logistic concepts and the associated requirements for effective maintenance of lunar exploration systems for Apollo (LESA). To accomplish this objective, conceptual design studies and analytical studies were performed.

Refer to the following final report for details of the study:

"Operations and Logistics Study of Lunar Exploration Systems for Apollo," Contract No. NAS8-11361, Report No. FZM-435 or NASA CR-62016, General Dynamics/Ft. Worth, February 26, 1965, UNCLASSIFIED.

Contract Data

1. Contractor: General Dynamics/Ft. Worth
2. Contract No.: NAS8-11361
3. Period of Performance: June 64 - March 65
4. Contract Amount: \$139,000
5. Technical Supervisor: E. Waggoner

D. COMMUNICATIONS AND CONTROL (LESA)

Objectives and Results

The fundamental objective of this study was to define the most practical communication system for incremental buildup of a lunar exploration system for Apollo. Briefly, the communications and control system must provide command, voice, telemetry, and video transmission and reception capabilities between the Moon and the Earth and communications between points on the lunar surface, both within line-of-sight and beyond line-of-sight.

The results of the effort are given in the following final report:

"Communications and Control, Lunar Exploration Systems for Apollo," Contract No. NAS8-11357, Report No. SO-113 or NASA CR 63175, Westinghouse Corporation, March 1965, UNCLASSIFIED.

Contract Data

1. Contractor: Westinghouse Corporation
2. Contract No.: NAS8-11357
3. Period of Performance: June 64 - April 65
4. Contract Amount: \$82,000
5. Technical Supervisor: F. Digesu

E. HUMAN FACTORS AND ENVIRONMENTAL CONTROL (LESA)

Objectives and Results

This study investigated human factors and environmental control/life support systems for advanced lunar exploration missions to be performed as a part of the LESA program. The LESA missions represent a substantial increase in lunar operational capability beyond the few hours lunar surface stay-time provided by project Apollo. Man is considered to be indispensable in these missions and must be provided with an environment and with the various materials needed to meet his physiological and psychological requirements. This effort considered these needs.

The results of the study are documented in the final report listed below:

"Study of Human Factors and Environmental Control-Life Support Systems, Lunar Exploration Systems for Apollo," Contract No. NAS8-11447, Report No. SS 3243-1, Garrett-Airesearch Manufacturing Company, Not dated, UNCLASSIFIED.

Contract Data

1. Contractor: Garrett-Airesearch Manufacturing Company
2. Contract No.: NAS8-11447
3. Period of Performance: August 64 - March 65
4. Contract Amount: \$99,000
5. Technical Supervisor: M. Vaccaro

## SECTION IV. PLANETARY STUDIES

### A. PLANETARY TRANSPORTATION SYSTEMS MODEL

#### Objectives and Results

This was a continuation of a study initiated with FY-63 funds. The objective was to provide a reliable, flexible, and comprehensive automated matrix model of planetary transportation systems that would give quantitative results in terms of significant figures of merit for the evaluation of advanced propulsion systems in connection with potential mission requirements. A synthetic evaluation method incorporating the information of related previous studies was to be used. This initial model was to be capable of further growth by making provisions for incorporating additional significant system parameters in order to improve its predictive accuracy.

The results of this work, including previous efforts, are documented in the following final reports:

1. "Space Technology Analysis and Mission Planning (STAMP) Detailed Technical Report," Contract No. NAS8-11057, Report No. CR-64-16, Martin-Denver, January 1965, UNCLASSIFIED.
2. "STAMP Space Technology Analysis and Mission Planning," Contract No. NAS8-11084, Report No. GD/A AOK 65-001/-1/-2/-3/-4, General Dynamics-Astronautics, 1965. UNCLASSIFIED.

#### Contract Data

1. Contractor: Martin-Denver
  - a. Contract No.: NAS8-11057
  - b. Period of Performance: May 64 - March 65 (Follow-on)
  - c. Contract Amount: \$49,000 (Follow-on); \$124,000 (Total)
  - d. Technical Supervisor: V. Gradecak
2. Contractor: General Dynamics-Astronautics
  - a. Contract No.: NAS8-11084
  - b. Period of Performance: May 64 - February 65 (Follow-on)
  - c. Contract Amount: \$49,000 (Follow-on); \$122,000 (Total)
  - d. Technical Supervisor: V. Gradecak



B. MANNED MARS AND VENUS EXPLORATION

Objectives and Results

The broad objective of this study was to examine the aspects of manned missions to Venus and/or Mars with primary reliance on Saturn V modification and Post Saturn as ELV's and on chemical (O<sub>2</sub>/H<sub>2</sub>) and nuclear (solid core reactor) engines as the principal propulsion systems of the heliocentric interorbital space vehicle (HISV).

The results of the study are contained in the following final report:

"Manned Mars and Venus Exploration Study," Contract No. NAS8-11327, Report No. GD/C AOK 65-002, General Dynamics/Convair, June 8, 1965, UNCLASSIFIED.

Contract Data

1. Contractor: General Dynamics/Convair
2. Contract No.: NAS8-11327
3. Period of Performance: June 64 - January 65
4. Contract Amount: \$200,000
5. Technical Supervisor: H. Ruppe

C. LOW ACCELERATION SPACE TRANSPORTATION SYSTEMS

Objectives and Results

The objective of this effort was to assess the feasibility of accomplishing useful manned Mars missions during the period 1975-1985 using a combination of chemical, nuclear rocket, and nuclear-electric propulsion. The optimization criterion was specified as minimum initial mass in Earth orbit.

Results and details of the study are contained in the following final reports:

1. "Study of Low-Acceleration Space Transportation Systems," Contract No. NAS8-11309, Report No. D-910262-3, United Aircraft Corporation, July 1965, UNCLASSIFIED.
2. "Study of Low Acceleration Space Transportation Systems, Phase I Study Effort," Contract No. NAS8-11423, Report No. 65SD4315, General Electric Company, June 30, 1965, UNCLASSIFIED.

Contract Data

1. Contractor: United Aircraft Corporation
  - a. Contract No.: NAS8-11309
  - b. Period of Performance: June 64 - June 65
  - c. Contract Amount: \$85,000
  - d. Technical Supervisor: V. Gradecak
  
2. Contractor: General Electric Company
  - a. Contract No.: NAS8-11423
  - b. Period of Performance: June 64 - June 65
  - c. Contract Amount: \$77,000
  - d. Technical Supervisor: V. Gradecak

D. MANNED MARS SURFACE OPERATIONS

Objectives and Results

This study was concerned with the scientific objectives of manned exploration of Mars, and with the relevant mission and engineering implications of the surface operations. Specifically, the objectives were to: Develop a detailed description of the scientific activities to be performed on and about the planet; investigate methods of relative worth assessment of alternative scientific activities; determine necessary engineering support for exploration activities; design two specific manned Mars missions, one short and one long stay-time; and develop logic for a computer program to study a wide range of missions.

The details of the study are contained in the following final report:

"Manned Mars Surface Operations Final Report," Contract No. NAS8-11353, Report No. RAD-TR-65-26, Avco Corporation, September 30, 1965, UNCLASSIFIED.

Contract Data

1. Contractor: Avco Corporation
2. Contract No.: NAS8-11353
3. Period of Performance: July 64 - September 65
4. Contract Amount: \$132,000
5. Technical Supervisor: V. Gradecak

E. MISSION REQUIREMENTS: MANNED MARS AND VENUS EXPLORATION

Objectives and Results

The basic objectives of this effort were the development of "criteria of choice" and methods of parametrically analyzing and evaluating the payloads, vehicles, mission modes, and missions proposed for manned Mars and Venus missions. Tasks accomplished included: Determination of basic payload for selected types of missions; performance of an analysis of failure and abort possibilities; analysis of mission yield and values (mission success probability, cost, development risk, cost/effectiveness); evaluation of the role of unmanned probes in support of manned missions; and determination of the development time and cost schedules required to perform the selected missions.

The results of the study are documented in the following final report:

"A Study of Mission Requirements for Manned Mars and Venus Exploration," Contract No. NAS8-11318, Report No. FZM-4366, General Dynamics/Ft. Worth, May 13, 1965, UNCLASSIFIED.

Contract Data

1. Contractor: General Dynamics/Ft. Worth
2. Contract No.: NAS8-11318
3. Period of Performance: June 64 - April 65
4. Contract Amount: \$192,000
5. Technical Supervisor: J. Smith